XXXII. *On the progressive compression of water by high degrees of force, with some trials of its effects on other fluids.* *By* J. Perkins. *Communicated by* W. H. Wollaston, *M. D. V.P.R.S. May* 25.

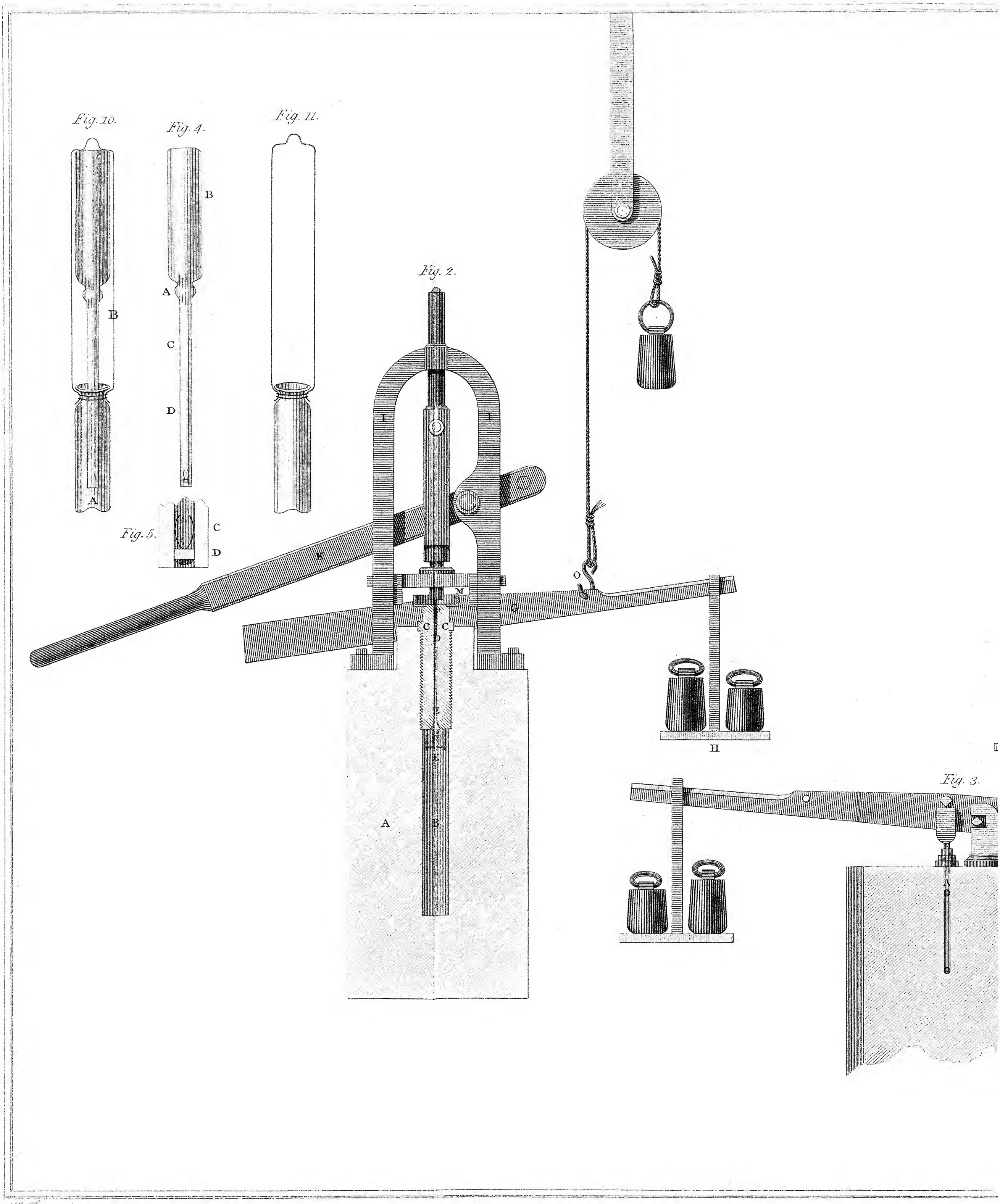
Read June 15, 1826.

The apparatus suggested by me in a paper read before the Royal Society the 22nd of June, 1820, on the compressibility of water, having now been completed, I will first describe its construction, and then give an account of the experiments already made with it.

Fig. 1. In the accompanying drawing, Plate XX. is a view of the compressing machine, and fig. 2 is a sectional view of the same, of which the following is a description. A, is a cylinder of gun metal, the length of which is 34 inches, and its external diameter $13\frac{1}{2}$ inches; B, is the receiver of the compressor, being $1\frac{1}{2}$ inch in diameter, and 29 inches long; C, is the barrel of a steel pump, $8\frac{1}{2}$ inches long and $1\frac{1}{4}$ inches diameter, on the outside of which a screw is cut 7 inches in length, by which it is finally united to the compressor; D, is the chamber or caliber of the pump, $\frac{5}{16}$ of an inch in diameter, and continuing of the same size throughout the whole length, excepting a conical enlargement at the bottom and top of the pump; the bottom cone receives the valve B when opening inwards; F, the piston or plunger of steel, most accurately fitted to the bore of the pump, having its lower extremity hollowed out to a semi-elliptical cup, with a very thin edge, the expansion of which during the

descent of the piston occasions it to be water-tight, without need of any stuffing. The lever G, which in this view passes behind the pump, is part of the apparatus for indicating the force of compression. Fig 3, represents a section of the indicator. A, is a cylindrical tube, communicating with the receiver of the compressor, and of such dimensions that its area is equal to $\frac{1}{14}$ of a square inch. Hence the number of pounds pressing on its piston by means of the lever G, indicates directly the number of atmospheres used for compression; since the arms of the lever are in proportion of 10 to 1, and its weight counterpoised by means of the hook O and weight, fig. 2, every pound in the scale represents 10 atmospheres of compressing force.

For the purpose of measuring the diminution of bulk that water undergoes, a glass piezometer, fig. 4, is used for containing it. This consists of an elongated bulb, nearly four inches in length and about $\frac{3}{4}$ of an inch in diameter, with a tube of regular bore, 9 inches long and about $\frac{1}{8}$ of an inch diameter internally. By weighing the quantity of quicksilver contained in this instrument when full, and ascertaining the weight contained in a given length of the tube alone, it was found that the whole content was equal to a tube of 190 inches long, having the diameter of the contracted part of the piezometer. Fig. 5, shows a section of the bottom of the piezometer, containing a small disk of steel D, and above it a delicate hair spring C, of sufficient strength to retain its position after being pressed upwards in the tube, so as to serve as register of the degree of compression that has been effected. Fig. 11, is a phial containing a small quantity of quicksilver, in which the piezometer, full of water, with its



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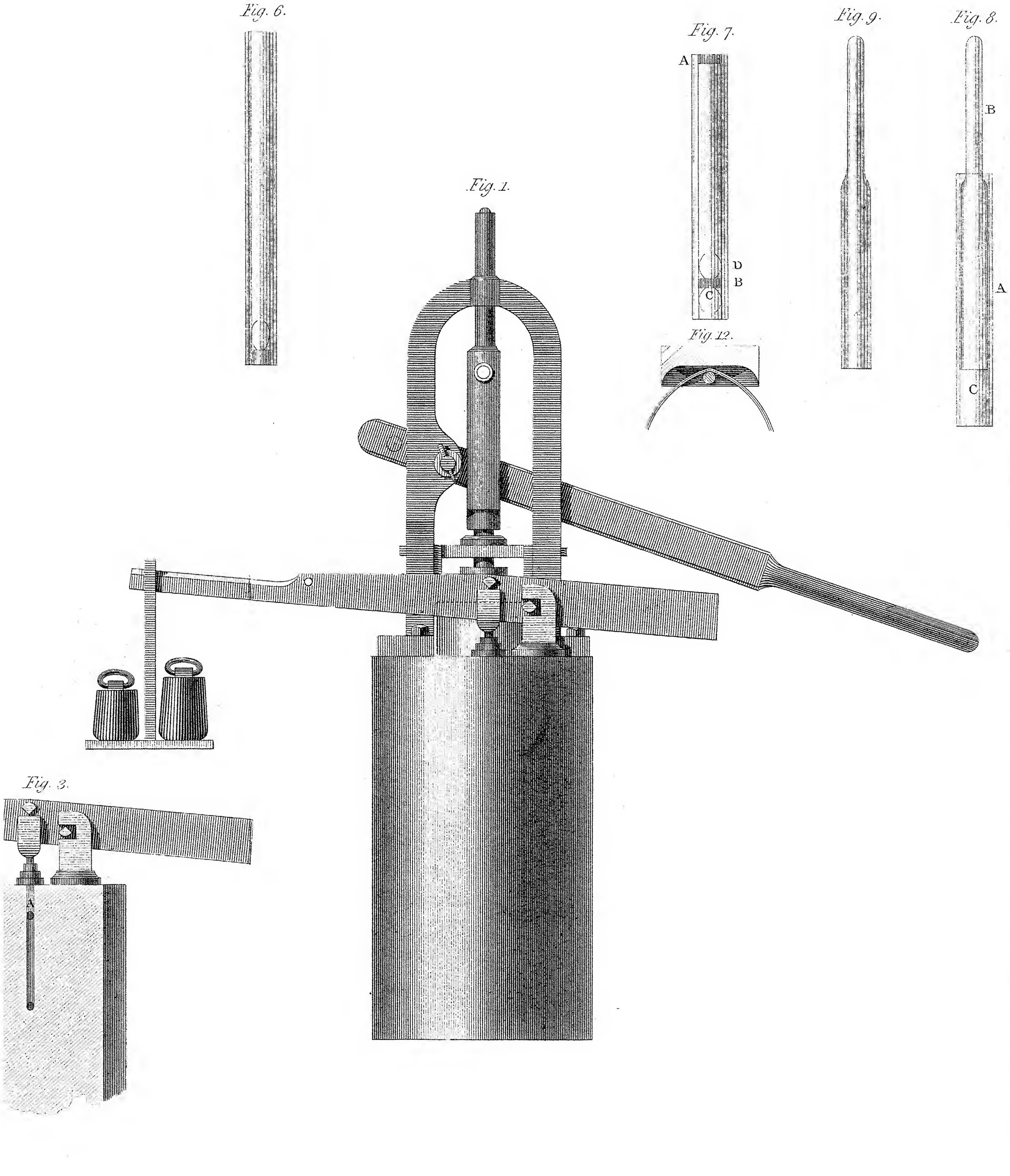

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register and disk, is to be inverted for experiment, as shown fig. 10.

The piezometer so arranged was then placed in the receiver of the compressor, which was filled with water, and kept at a temperature of 50 degrees FAHRENHEIT. The steel pump C, was next screwed firmly into its upper end, which is $\frac{1}{2}$ an inch longer than the screw or body of the pump, entering a recess of the cylinder of the compressor, of about $\frac{1}{4}$ of an inch in depth, which it exactly fitted. Between the head of the pump and the bottom of the recess was placed a collar of lead, for the purpose of making a more perfect joint.

The frame supporting the piston and pump handles was next screwed to the cylinder; about $\frac{1}{2}$ an inch of the upper end of the pump was bell-mouthed, the better to receive the piston, which rises quite out of the pump. Two desirable objects are effected by the piston leaving the chamber at each stroke, *viz.* 1st. It allows the water to fill the pump in the simplest manner; 2nd. The piston at each stroke receives a portion of the oil, which floats on the surface of the water in the cup M, which is of great consequence in high pressure. The piston F, contracts as it enters the bell mouth of the pump, which, together with the pressure of the water against the interior of the piston, causes it to fit as perfectly as the leather cup in the barrel of an air pump. All being ready, the pump was set to work, and as soon as the intended pressure was known to be effected by use of the valve, the pressure was gradually taken off, by unscrewing the pump C. The piezometer being removed from the compressor, the indicating spring was found raised in the tube, more or less, according to the power employed. The greatest amount

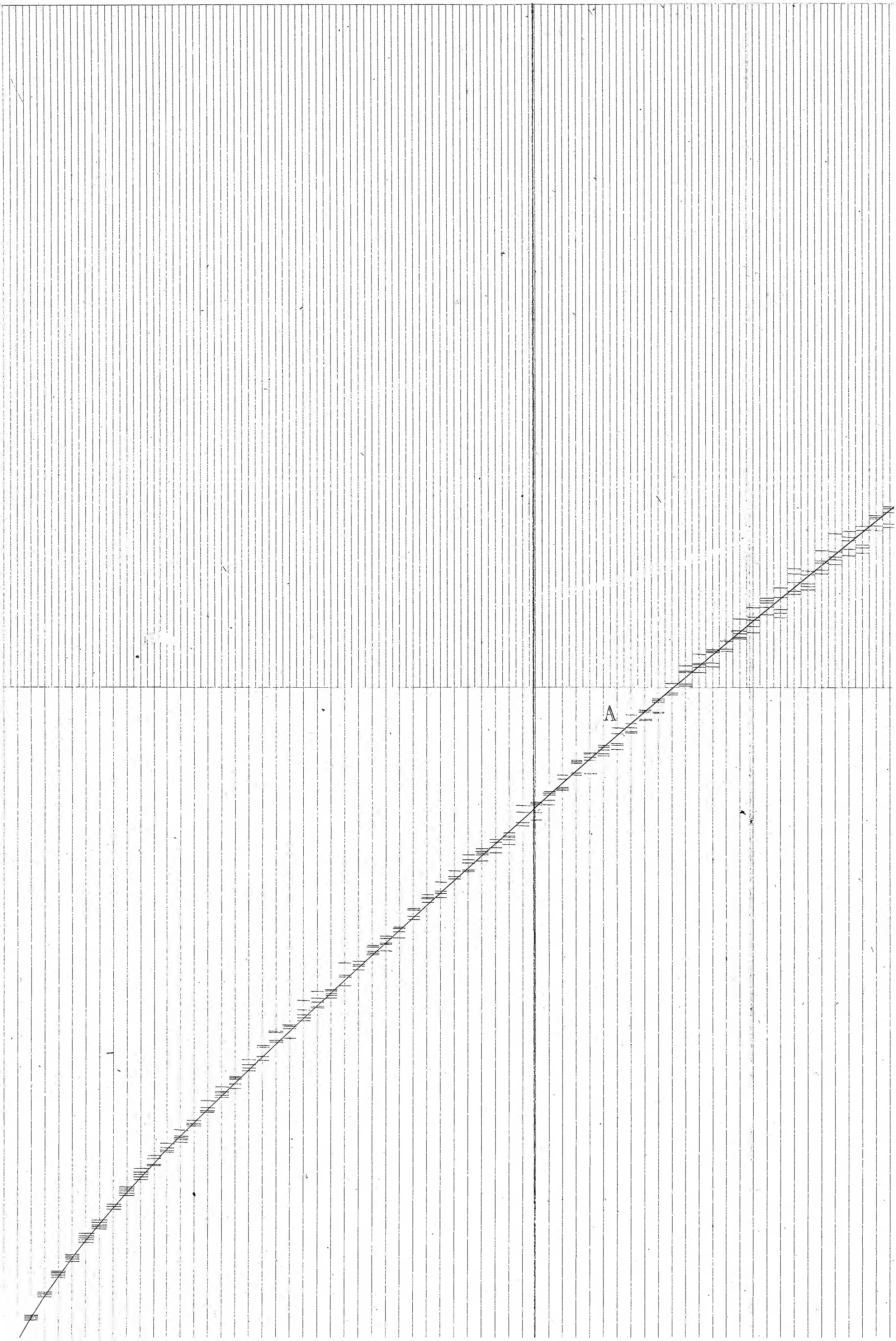
of which this apparatus admitted was 1000 atmospheres; being equal to 14,000 pounds to the square inch.

In order to estimate (though less accurately) higher degrees of compression, I had another piezometer, fig. 6, eight inches long, ground internally, perfectly cylindrical, and stopped at its upper extremity, with a flat disk of glass cemented into it. This tube I filled with water, and subjected it to a pressure of 2000 atmospheres. After repeating this experiment a great number of times, the average of the result showed that the column of water, 8 inches long, was compressed $\frac{2}{3}$ of an inch, or $\frac{1}{12}$ part of its length.

For the purpose of representing the law of condensation of water by different degrees of compressing force, I had a plate, 2, engraved, with parallel lines of $\frac{1}{10}$ of an inch a-part, to which the measure taken in each experiment was immediately transferred.

After the results of 5 experiments had been thus laid down for every 10 atmospheres, as far as 1000, a curve line has been drawn through the mean of them, as near as could be done to preserve a regular curve line. It may readily be seen, that there are various irregularities observable; but as the original records remain upon the plate, those who choose to theorize upon the subject, have the means of drawing any other curve that may suit their views of the true law of condensation.

With the same apparatus, I also made experiments on the compression of other fluids. The most remarkable result I obtained was with concentrated acetic acid; which, after compression with a force of 1100 atmospheres, was found to be beautifully crystallized, with the exception of about $\frac{1}{10}$ part of fluid, which, when poured out, was only slightly acid,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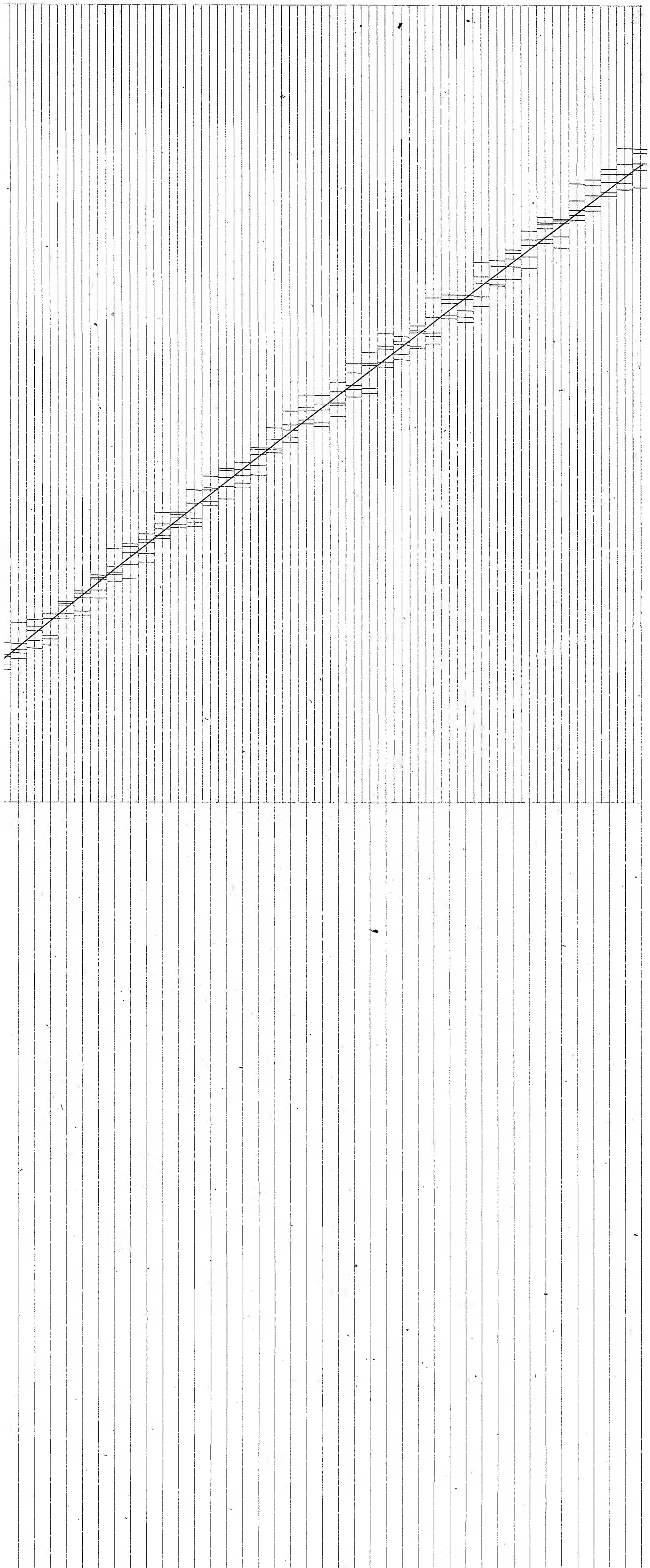
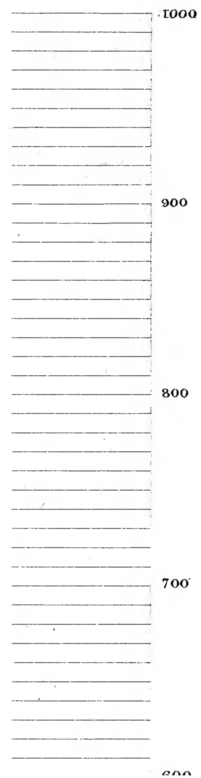


Atmosphères.
10
100
200
300
400
500
600


1000
900
800
700

I next applied the apparatus to the compression of aëriform fluids.

A gasometer B, was filled half full of water; it was then inverted, and placed in receiving tube A, as represented in fig. 8: it was found that, under a pressure of 500 atmospheres, the whole of the air was taken up by the water; but none of it was given out when the pressure was taken off.

As it might be supposed that even glass was pervious to water by such a force, a small phial was made air-tight, by fitting into its neck a well-ground glass stopper. It sustained pressure of 500 atmospheres without change, and was perfectly dry within, although it remained under that pressure 15 minutes. It was next subjected to a pressure of 800 atmospheres, and when taken out was found to be crushed to atoms.

In the course of my experiments on the compression of atmospheric air, by the same apparatus which had been used for compressing water, I observed a curious fact, which induced me to extend the experiment; *viz.* that of the air beginning to disappear at a pressure of 500 atmospheres, evidently by partial liquefaction, which is indicated by the quicksilver not settling down to a level with its surface. At an increased pressure of 600 atmospheres, the quicksilver was suspended about $\frac{1}{8}$ of the volume up the tube or gasometer; at 800 atmospheres, it remained about $\frac{1}{3}$ up the tube; at 1000 atmospheres, $\frac{2}{3}$ up the tube, and small globules of liquid began to form about the top of it; at 1200 atmospheres, the quicksilver remained $\frac{3}{4}$ up the tube, and a beautiful transparent liquid was seen on the surface of the quicksilver, in quantity about $\frac{1}{2000}$ part of the column of air. The gasometer, fig. 9,

was at another time charged with carburetted hydrogen, and placed in the receiving tube A, fig. 8, with its mouth immersed in the quicksilver C; it was subjected to different pressures, and it began to liquefy at about 40 atmospheres, and at 1200 atmospheres the whole was liquefied.

These instances of apparent condensation of gaseous fluids were first observed in January, 1822; but for want of chymical knowledge requisite to ascertain the exact nature of the liquids produced, I did not pursue the inquiry further; and as the subject has been taken up by those who are eminently qualified for the investigation, I need not regret my inability to make full advantage of the power I had the means of applying.

I have been desirous of ascertaining the law of condensation of gaseous fluids, at the high degrees of pressure; but as the apparatus for the compression of water, which requires to be made sensible at its lower extremity, is by no means adapted to show the higher degrees of compression of gases, a suitable apparatus requires to be made for such experiments; which I shall hope to make the subject of a future communication.

This Table shows, in inches and parts, the compression of a column of 190 inches of water, corresponding to every 10 atmospheres to 1000 inclusive.

Atmos.	Inches.	Inches.	Inches.	Inches.	Inches.	Atmos.	Inches.	Inches.	Inches.	Inches.	Inches.
10	0.176	0.191	0.200			510	5.110	5.147	5.170	5.180	5.241
20	0.350	0.367	0.380	0.390		520	5.150	5.270	5.255	5.267	5.280
30	0.522	0.540	0.550	0.560		530	5.260	5.275	5.340		
40	0.665	0.680	0.693	0.700	0.715	540	5.355	5.363	5.393	5.413	5.500
50	0.784	0.800	0.810	0.825	0.840	550	5.397	5.443	5.491	5.513	5.587
60	0.927	0.943	0.950	0.970	0.991	560	5.530	5.583	5.620	5.635	5.653
70	1.026	1.040	1.055	1.067	1.090	570	5.510	5.545	5.570	5.650	5.730
80	1.170	1.190	1.200			580	5.680	5.700	5.765	5.830	5.865
90	1.265	1.285	1.300	1.327	1.333	590	5.710	5.737	5.751	5.820	5.850
100	1.385	1.400	1.420	1.440	1.465	600	5.831	5.860	5.913	5.930	6.000
110	1.485	1.495	1.537	1.560		610	5.897	5.940	5.955	5.991	6.120
120	1.585	1.595	1.617	1.647		620	5.960	6.013	6.070	6.100	6.140
130	1.650	1.670	1.685	1.700	1.745	630	5.977	6.020	6.040	6.145	6.171
140	1.780	1.790	1.800	1.830		640	6.150	6.186	6.230	6.247	6.258
150	1.880	1.893	1.915	1.967		650	6.170	6.193	6.280	6.310	6.325
160	1.990	2.010	2.025	2.040	2.070	660	6.280	6.330	6.397	6.410	6.423
170	2.050	2.090	2.120	2.140	2.150	670	6.383	6.421	6.440	6.470	6.590
180	2.190	2.200	2.233	2.267		680	6.400	6.491	6.563	6.600	6.620
190	2.267	2.291	2.360	2.370		690	6.500	6.555	6.627	6.643	6.681
200	2.395	2.413	2.470	2.480		700	6.653	6.670	6.713	6.747	6.813
210	2.427	2.495	2.515	2 530		710	6.720	6.740	6.781	6.795	6.813
220	2.550	2.570	2.593	2.630	2.700	720	6.725	6.750	6.770	6.870	6.950
230	2.643	2.650	2.687	2.710	2.763	730	6.855	6.880	6.951	6.965	7.040
240	2.715	2.740	2.750	2.770	2.783	740	6.900	6.980	7.037	7.080	7.093
250	2.800	2.870	2.890	2.977		750	6.961	6.991	7.040	7.080	7.121
260	2.923	2.953	2.970	2.990		760	7.050	7.110	7.177	7.211	7.224
270	3.035	3.050	3.060	3.090	3.100	770	7.187	7.29	7.216	7.275	7.343
280	3.060	3.110	3.120	3.150	3.170	780	7.247	7.280	7.320	7.350	7.450
290	3.157	3.205	3.230	3.240		790	7.370	7.400	7.450	7.470	5.550
300	2.297	3.320	3.365	3.373		800	7.350	7.375	7.450	7.491	7.445
310	3.420	3 450	3.460	3.480		810	7.410	7.480	7.497	7.570	7.627
320	3.450	3.490	3.500	3.567		820	7.540	7.587	7.610	7.690	7.745
330	3.595	3.615	3.653			830	7.563	7.590	7.737	7.745	7.815
340	3.641	3.650	3.710	3.733	3.770	840	7.723	7.760	7.840	7.857	7.940
350	3.720	3.767	3.780	3 791	3.813	850	7.775	7.810	7.867	7.885	7.920
360	3.785	3.823	3.863	3 887		860	7.843	7.860	7.943	7.955	7.990
370	3.847	3.880	3.895	3.910	3.933	872	7.870	7.920	7.940	8.033	8.160
380	3.980	4.000	4.800	4.129		880	8.027	8.050	8.130	8.150	8.180
390	4.013	4.080	4.140	4.150	4.159	890	8.500	8.040	8.080	8.147	8.173
400	4.133	4.170	4.210	4.220	4.231	900	8.110	8.170	8.260	8.290	8.385
410	4.245	4.253	4.263	4.320	4.350	910	8.237	8.247	8.277	8.360	8.393
420	4.353	4.365	4.445	4.450	4.456	920	8.377	8.350	8.400	8.443	8.460
430	4.360	4.460	4.480	4.570	4.518	930	8.327	8.420	8.490	8.525	8.580
440	4.490	4.500	4.530	4.555	4.565	940	8.500	8,540	8.590	8.627	8.640 & 8.670
450	4.543	4.570	4.585	4.653	4.700	950	8.480	8.550	8.637	8.650	8.660
460	4.660	4.670	4.700	4.730	4.795	960	8.650	8.680	8.710	8.767	8.880
470	4.753	4.760	4.813	4.827	4.833	970	8.710	8.735	8.800	8.870	8.900
480	4.810	4.815	4.880	4.900	4.910	980	8.800	8.825	8.890	8.940	8.970
490	4.950	4.963	5 010	5.040		990	8.847	8.880	8.938	9.000	9.100
500	5.010	5.035	5.110	5.120	5.160	1000	8.855	8.973	9.005	9.076	9.100

It will appear, that at some pressures the result of only three or four experiments have been tabulated; this apparent omission arises from the entire coincidence of two or more of the experiments, and from my having omitted at the time to notice which were those which so agreed.